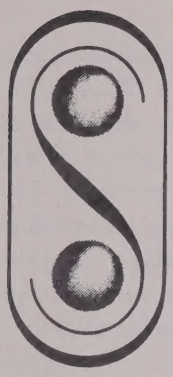

SPELLMAN
HIGH-VOLTAGE ELECTRONICS CORPORATION

BULLETIN STP-473

STANDARD TEST PROCEDURES FOR HIGH VOLTAGE POWER SUPPLIES

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OUR THIRD DECADE OF LEADERSHIP IN HIGH-VOLTAGE TECHNOLOGY.

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INTRODUCTION

The following pages provide generalized descriptions of the tests used by SPELLMAN HIGH VOLTAGE ELECTRONICS CORPORATION in its Quality Control program. These generalized descriptions cover tests on a large number of different models which vary widely in output voltage, output current, and other operating parameters.

Detailed test data sheets are available for most models. These individual test data sheets delineate the explicit requirements and permissible acceptance levels for each item to be tested.

For additional information, please contact the SPELLMAN Engineering/Test Department.

I. HIGH VOLTAGE POWER SUPPLY LOADING METHODS

A. *Constant Load*

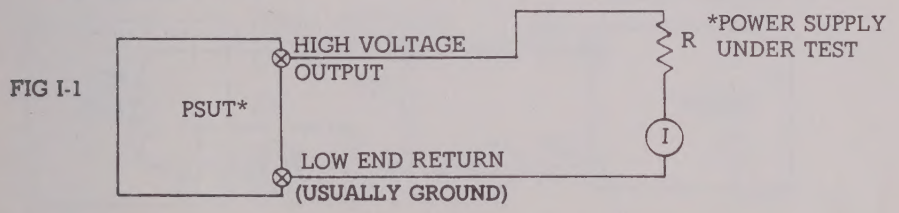


FIG I-1

Figure I-1 shows a resistor ("R") in series with a current monitor ("I"), across the terminals of the P.S.U.T.

CAUTION: The lead from the High Voltage Terminal should be high voltage wire. If high voltage wire is not available, ordinary hook-up wire may be used providing reasonable care is exercised to avoid contact with ground circuits.

Resistors must be selected with appropriate voltage and wattage ratings for the specified load requirements. Attention should be given to the physical mounting arrangement, in order to avoid breakdown.

The appropriate current monitor, "I", should be connected in series with the load resistor, "R", in the LOW END RETURN line. This holds the meter at safe, low potentials.

B. *CHANGING LOAD*

1. Manual Switch

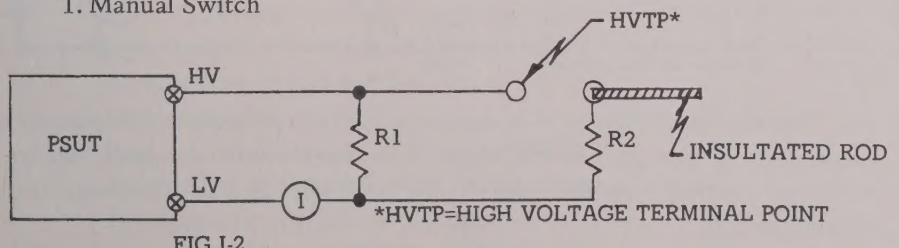


FIG I-2

Figure I-2 shows resistor R1 directly connected to the P.S.U.T. R1 is selected to load the P.S.U.T. for the *minimum* specified load. For a *NO LOAD* condition, R1 is infinite and, thus, open circuited.

Resistor R2 is selected as required to achieve the desired load condition. The "low end" of the R2 resistor is returned to the current monitor, I. The "high end" of the R2 resistor is connected by an appropriate lead to an insulated stick or rod ("Plexi-glas" or other acrylic material is recommended). A two-foot length should be adequate for most applications below 100 Kilovolts. Hold this stick in your hand, making sure that you grip it at the end opposite from the lead termination. This allows safe and easy connection to the High Voltage Terminal Point.

Note that when R2 is connected as shown, I indicates the total load current, the sum of the load in R1 and the load in R2.

When measurements are completed, the load is disconnected from the High Voltage Terminal Point, by manually removing the insulated rod from contact with the H.V.T.P. NOTE: when not connected to H.V.T.P., the "high end" of R2 as well as the "low end" are both at safe, low potentials with respect to ground, and are safe to handle.

2. Vacuum Switch

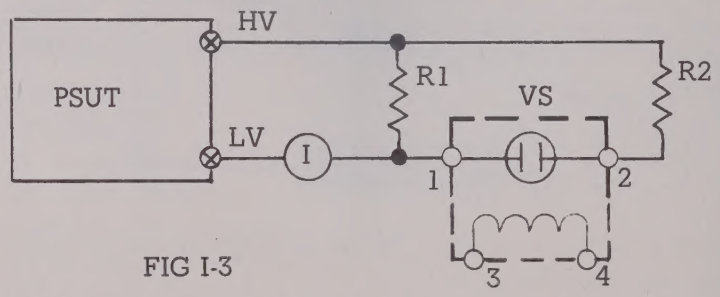
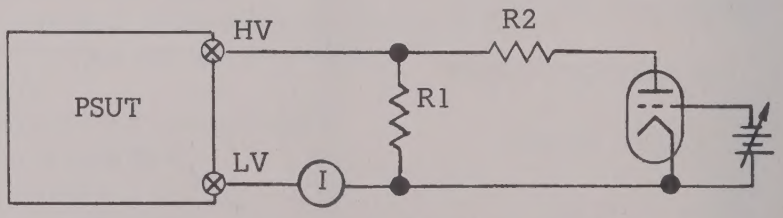


FIG I-3

VS in figure I-3 is a "relay" type contact which must be capable of "making" and "breaking" the voltage of the P.S.U.T., and handling the load current. Suitable vacuum switches are available from the ITT-Jennings Company in California for almost all power supplies manufactured by SPELLMAN. DC operation of the relay coil (at 3 and 4 of the Figure I-3) is desirable. Closing the contacts between 1 and 2 connects the load R2 to the supply. Opening the contacts opens the load. NOTE: the switch is connected in the "low end" of the load resistor R2.

3. Electron Tube Switch

FIG I-4



The circuit of Figure I-4 is similar to the vacuum switch arrangement of Figure I-3. If the grid of the tube is switched from near zero bias to a sufficient negative bias, the tube can be controlled as a switch similar to the vacuum switch.

In addition, the tube can be controlled to provide continuous load adjustment by proper variation of the grid bias.

An easy method of attaining bias is by the use of an adjustable cathode resistor.

The Manual switch and Vacuum switch arrangements, explained in the

previous paragraphs, (I.B 1-2) are applicable for power supplies with either positive or negative polarity. The electron tube circuit of Figure I-4 is shown for a high voltage power supply with positive polarity only. A tube can be used for power supplies with negative polarity by connecting the plate end to low voltage and the cathode end to high voltage. In this case, since the filament and grid supplies will be at high voltage, isolation techniques must be used.

II. VOLTAGE CALIBRATION AND RANGE

This paragraph describes the test set up and method used to measure the output voltage at no load and in accordance with the specifications of the specific test data sheet for a given power supply.

A. *Test Set-up*

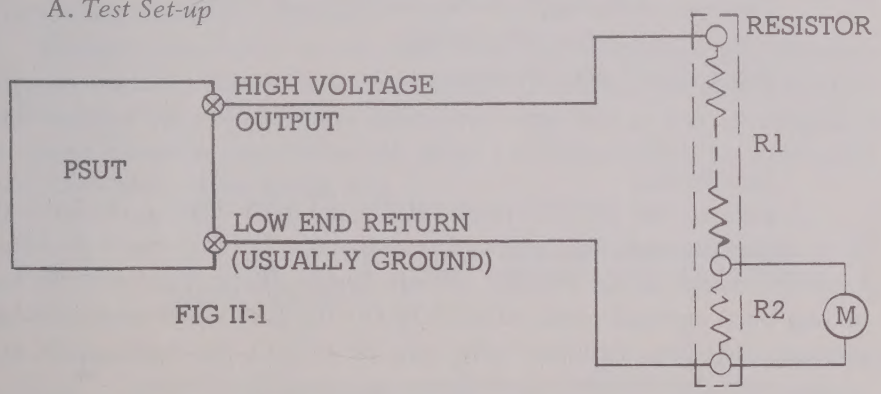


FIG II-1

1. *RESISTOR DIVIDER*

SPELLMAN standard test resistor divider networks are constructed with resistor values, as follows:

a. R1: 1000 Megohms total resistor string consisting of 12 resistors, 75 Megohms each and 2 resistors, 50 Megohms each, all connected in series. The resistors are precision metal film types rated for 10 Kilovolts DC maximum and 5 Watts maximum. NOTE: the resistors are operated well under these maximum limits to assure stability of calibration.

b. R2: 1 Megohm, military style RN60E1004F, precision metal film resistor.

c. Mechanical Construction: The SPELLMAN resistor divider is housed in a "plexi-glas" cylinder approximately 7" in diameter and 12" high, terminated with anti-corona toroidal shapes at top and bottom to minimize corona and leakage.

d. Divider Specifications

Ratio: 1000:1 within ± o.5% at 100KVDC
Voltage rating: 100 Kilovolts DC maximum
Temperature Coefficient: 50 ppm
Voltage Coefficient: ± 0.5% / 100KV
Stability: 10 ppm/hour
50 ppm/8 hours
100 ppm/24 hours
Calibration Interval: 90 days

2. *MONITOR INSTRUMENTATION*

The instrument used to measure the divider output voltage must have high input impedance in order to minimize the error of reading across the 1 Megohm resistor (R2). SPELLMAN uses either of the two instruments described below for monitor (V) in the test set-up diagram, Figure II-1, depending on the resolution requirements.

1. John Fluke Model 891A
   Accuracy of reading including stability: ± 0.01% of input
   Input impedance at null: infinite
   Resolution: 10 ppm of range

2. John Fluke Model 895A
   Accuracy of reading including stability: ± 0.0025%
   Input impedance at null: infinite
   Resolution: 1 ppm of range

Test Method

1. Connect the *RESISTOR DIVIDER* and *MONITOR* as shown in the Test Set-up diagram, Figure II-1. The connection between the high voltage output terminal of the P.S.U.T. (Power Supply Under Test) and the high voltage input terminal of the RESISTOR DIVIDER should be made with high voltage lead wire. Ordinary wire may be used if the lead is kept at a reasonable distance from ground to prevent voltage breakdown.

2. Connect the P.S.U.T. to a source of input power in accordance with the unit specification. Appropriate input voltage and current monitoring equipment should be included in the test set-up.

3. All required external adjustment controls should be connected in accordance with the unit specification.

Using the specific test data sheet which establishes the proper input voltage conditions and output voltage settings, measure the output voltage according to the above procedures.

4. Energize the P.S.U.T., exercising reasonable precautions against high voltage hazards.

5. Measure the output voltage under desired conditions of input voltage and adjustment of voltage controls.

6. The above measurement is described for what is essentially a "NO LOAD" condition. This is due to the fact that the SPELLMAN Resistor Divider has an input impedance of 1000 Megohms draining negligible load current in almost all cases.

Measurements under load may be made as desired by connecting appropriate high voltage load resistors, or other loading devices, across the PSUT. Current monitors should be connected in series with the load resistors in the grounded end to keep the meters at safe potentials. NOTE: See Section I for additional information on loading methods.

III. OUTPUT VOLTAGE REGULATION, STATIC AND DYNAMIC

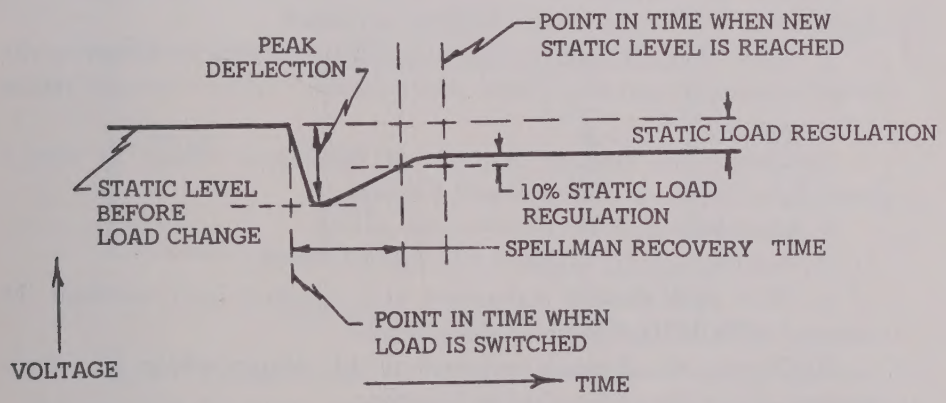
A. *DEFINITION*

In general, most power supply manufacturers in the United States limit the use of the term "regulation" to variations in the output voltage which result directly from changes in the input power source and/or the load resistance.

"Regulation" then, as defined by SPELLMAN, and most other manufacturers, specifically *excludes* variations resulting from changes in *temperature* and *time*. Thus, regulation is measured at "constant temperature" and "short" time intervals, where "short" means the time required to make the measurements.

In addition to the two basic components of regulation, i.e. LOAD regulation and LINE REGULATION, regulation is further differentiated as STATIC or DYNAMIC variations.

Dynamic regulation is concerned with the output voltage transient response resulting from a line or load change. Of interest are peak deflection and recovery time. SPELLMAN defines recovery time as that time required to return from the peak deflection point to within 10% of the new static level. The sketch below details this.



B. Test Set-up, *STATIC REGULATION*

1. Connect the output voltage monitor circuit as described in Section II.

2. Connect the PSUT to a source of input power in accordance with the unit specification. Appropriate input voltage and current monitoring equipment should be included in the test set-up. Provide for input power adjustability as required by the specification.

3. Select a loading method (as described in Section I) which is suitable to the unit specification. Make the necessary connections.

C. Test Method, *STATIC LOAD REGULATION*

1. With input voltage maintained constant, make the specified load change using one of the techniques of Section I.

2. Observe the change in output voltage as read on the voltage monitor. Record for "LOAD ON".

3. Repeat for "LOAD OFF"

4. The above measurements may be made at minimum, maximum and

nominal input voltage conditions in accordance with the unit specification. They also may be made at different output voltage conditions, as specified.

D. Test Method, *STATIC LINE REGULATION*

1. The same set-up as "B" above is used.

2. With output voltage level and load condition set as per specification, adjust the input voltage from minimum to maximum.

3. Observe the change in output voltage as read on the voltage monitor. Record.

E. Test Set-up, *DYNAMIC REGULATION*

1. To monitor dynamic output voltage variations, SPELLMAN uses a compensated divider oscilloscope probe, TEKTRONIX type P6015. This probe may be used up to 20 Kilovolts DC. The input resistance of the divider is 100 Megohms; this input resistance constitutes a load which must be taken into account.

2. Dynamic load variations can be achieved by either the vacuum switch or electron tube switch described in Section I. To facilitate the oscilloscope display an appropriate square-wave or pulse drive is required for the switch.

3. Dynamic line variations are rarely required. Methods for switching the input voltage must be developed for each individual case.

F. Test Method, *DYNAMIC LOAD REGULATION*

1. With input voltage maintained constant at its nominal value, establish a square-wave load or pulse-load condition as desired.

2. Check that the load current is switching properly by observing the current wave-shape across a current sensing resistor in the "low end" return of the power supply.

3. Observe the dynamic response of the output voltage by using a compensated divider as described in E-1 above.

4. Record the results.

G. Test Method, *DYNAMIC LINE REGULATION*

1. With load current maintained at a constant level, establish the necessary input voltage switching characteristic.

2. Observe the dynamic response of the output voltage by using a compensated divider as described in E-1 above.

3. Record the results.

IV. OUTPUT CURRENT REGULATION

This power supply parameter applies to "Constant Current" or "Current Regulated" supplies. All aspects of "regulation" as described in section III above apply here except for the method of measurement.

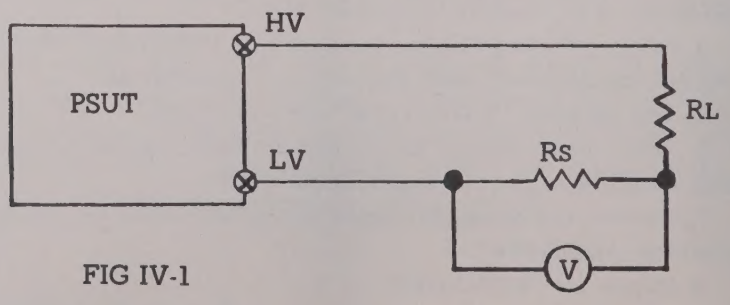


FIG IV-1

In Figure IV-1, the load resistance is represented by RL. In a current regulated supply, the load resistor, RL, changes from zero, at the short circuit condition, to some finite value at the rated output voltage condition. The supply cannot maintain regulation into an open circuit, obviously. Thus, load changes are accomplished by "shorting" a portion of the rated load resistor.

A current sensing resistor Rs, in series with the "low end" of the power supply is used for monitoring the current by measuring the voltage across Rs. The Fluke Differential Voltmeter used in the voltage monitor circuit of Section II is used in this measurement also.

All tests and methods described in Section III are applicable.

V. RIPPLE

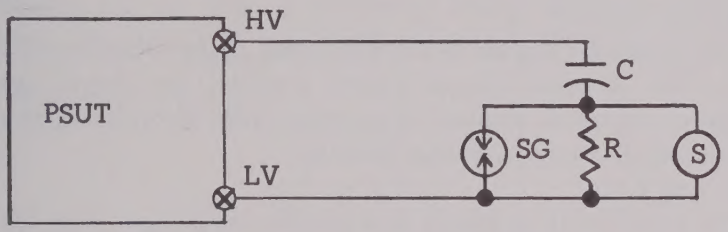


FIG V-1

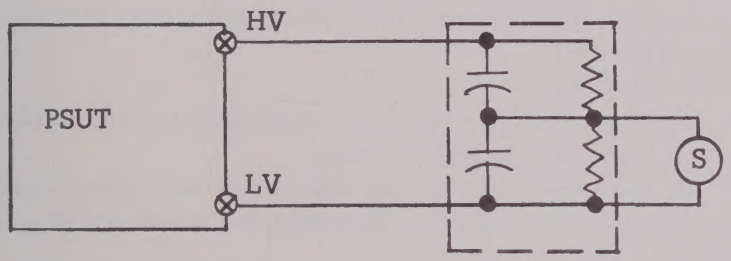


FIG V-2

Figure V-1 illustrates the technique of using a DC blocking capacitor, C, in series with the power supply output terminal, for the purpose of passing the AC component in the output voltage directly to the oscilloscope, S. Resistor, R, and spark gap, SG, protect the oscilloscope against surges in the output voltage which could be transferred directly through the blocking capacitor to the scope.

The value of C and R must be selected to pass the ripple frequencies of interest with negligible attenuation. The oscilloscope input impedance and frequency response also introduce an error which must be accounted for.

The error in 60 Hz ripple measurements is small for $C \geqslant 0.01uF$ and $R \cong 1$ Megohm. For high frequency components proportionally smaller capacitance values are acceptable.

Figure V-2 illustrates the use of the Tektronix divider for ripple measurements. Although the compensated divider gives an accurate measurement, it suffers from two deficiencies. First, a true no load ripple measurement cannot be made, since the divider itself has 100 Megohm input resistance. Second, when the power supply output ripple is relatively low, the 1000:1 divider ratio may attenuate the AC component at the divider output to a level which may be difficult to read.

B. Test Method

1. Set all operating parameters as required by the unit specified. These operating parameters must include all the following:

* Output Voltage setting
* Load Current condition
* Input Voltage condition

2. Read the ripple in peak-to-peak on the oscilloscope. Record.

3. Divide the measured peak-to-peak value by $2\sqrt{2}$ when RMS readings are desired.

VI. TEMPERATURE COEFFICIENT

A. *DEFINITION*

This parameter is given as the percentage change in output voltage (or current, for constant current power supplies) per degree (generally Centigrade) change in ambient temperature with all operating conditions other than temperature remaining constant.

B. Test Set-up.

The PSUT must be placed in a suitable temperature chamber which can be varied over the specified temperature range.

Wires must be brought out of the chamber from the power supply for connection to the monitor circuit of Section II and appropriate load circuits described in Section I.

C. Test Method.

1. Adjust power supply operating conditions for output voltage, input voltage, and load to the desired test levels.

2. Set the temperature to the desired low end value. Observe the voltage monitor until its value has been stable for at least one hour. Record voltage level.

3. Change the temperature setting to the desired high end value. Again wait until the voltage monitor reading has been stable for at least one hour. Record voltage level.

4. Let V_L= voltage at "low" end (low temperature condition)

V_H= voltage at "high" end (high temperature condition)

V_N= nominal voltage condition, where

$$V_L \geqslant V_N \geqslant V_H$$

T_H= "High" end temperature

T_L= "Low" end temperature condition

$$\text{Temperature Coefficient} = \frac{V_H - V_L}{V_N (T_H - T_L)} .100$$

VII. STABILITY

A. *DEFINITION*

This parameter is given as the percentage change in output voltage (or in current, for constant current power supplies), per period of time, with all operating conditions, including temperature remaining constant.

B. Test Set-up.

The P.S.U.T. must be placed in a suitable temperature chamber which can be varied over the specified temperature range.

Wires must be brought out of the chamber from the power supply for connection to the monitor circuit of Section II and appropriate load circuits described in Section I.

C. Test Method.

1. Adjust power supply operating conditions for output voltage, input voltage, load, and temperature to the desired test levels.

2. If possible, monitor the output voltage continuously from power supply turn-on. Measurements should be made as frequently as practical, particularly during the initial warm-up period.

Stability may be given as percentage change in output voltage (or current) per 10 minutes, per hour, per 8-hours, etc., as required.

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